Radiation Protection and Architecture Utilizing High Temperature Superconducting Magnets

Completed Technology Project (2011 - 2012)

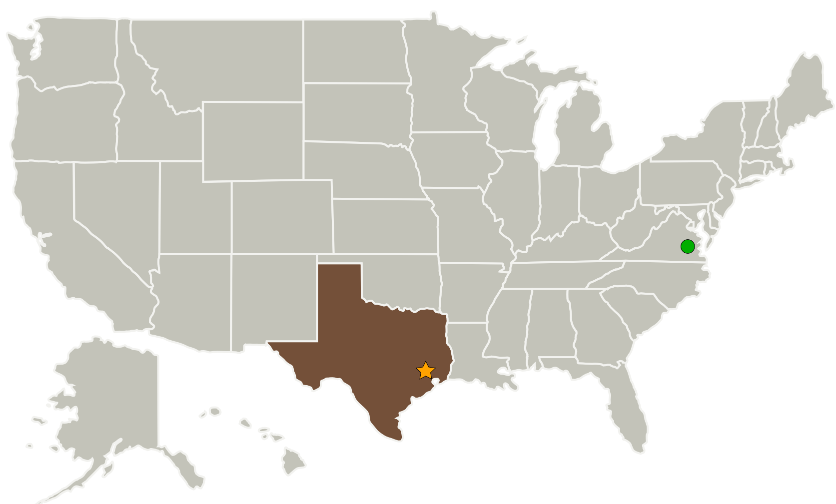
Project Introduction

Human space exploration exposes astronauts to particularly hazardous environments unique from Earth-based hazards. A substantial risk for exploration beyond the confines of the Earth's geomagnetic field is radiation exposure from energetic solar protons and Galactic Cosmic Radiation. The concept of shielding astronauts with magnetic/electric fields has been studied for over 40 years and has remained an intractable engineering problem. Superconducting magnet technology has made great strides in the last decade. Coupling maturing technology with potential innovative magnet configurations, this proposal aims to revisit the concept of active magnetic shielding. The focus of the proposed work is to analyze new coil configurations with current technology and compare shielding performance and design mass with alternate passive shielding methods.

Anticipated Benefits

Potential to improve in space crew protection from exposure to Solar Proton Events and Galactic Cosmic Radiation.

Primary U.S. Work Locations and Key Partners



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Organizations Performing Work	Role	Type	Location
★Johnson Space Center(JSC)	Lead Organization	NASA Center	Houston, Texas
Advanced Magnet Lab, Inc.	Supporting Organization	Industry	
●Langley Research Center(LaRC)	Supporting Organization	NASA Center	Hampton, Virginia
Università di Perugia	Supporting Organization	Academia	Perugia, Outside the United States, Italy

Primary U.S. Work Locations
Texas

Project Transitions

September 2011: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Johnson Space Center (JSC)

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

Program Manager:

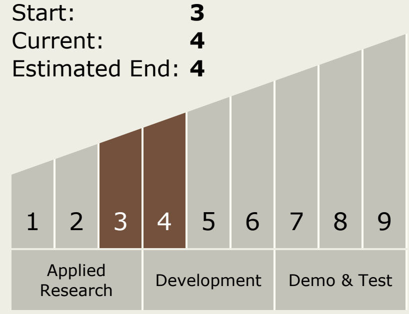
Eric A Eberly

Principal Investigator:

Shayne C Westover

Technology Maturity (TRL)

Start: **3**
Current: **4**
Estimated End: **4**



September 2012: Closed out

Closeout Summary: The NIAC one year study evaluated multiple coil geometri es including the Double Helix from AML and toroid designs. The Double Helix an d other toroid concepts have a constant, no gap transverse field for turning ioniz ed radiation, however significant loads on the habitat and between the coils resu lt in significant structural design architecture and mass. Most toroid configuratio ns result in a large field within the habitat requiring complex shielding from the magnetic field for the crew and electronics. The down-selected 6+1 solenoid coil array and compensator coil configuration minimizes both mass and in the cabin f ringe field technical issues. The concept of coil expansion using the Lorentz force with high temperature superconductors enables very large coil diameters to incr ease the integral BdL of the system for improved dose efficiency while keeping t o a reasonable launch mass and simplified assembly. Not only does the compens ator coil tune to minimize fringe fields entering the habitat, but also simplifies th e coil thermal management system by capturing the radiant heat from the habit at with cryocoolers. As a protection from SPE, analysis was completed for a 6m diameter by 10m length cylindrical habitat that resulted in 141 metric tons of 75 cm thick polyethylene providing similar protection as that from a 6+1 expanding coil array at 8 Tm with a simulated mass of 36 metric tons. The Blood Forming Organ (BFO) dose was ~50 mSv for a 180 hour SPE from October of 1989. This comparison maintained a constant habitable volume vice filling the volume with polyethylene for individual crew protection such as a storm shelter. Dose equival ent results for the 8 Tm configuration are comparable with annual dose equivale nts for a spacecraft in LEO with barrel-only BFO results at 309 mSv and total res ults with nearly naked end caps with an empty habitable volume at 451 mSv. Fo r comparison with the 150 mSv career limit, the body dose equivalent is 232 mS v for the 8 Tm barrel region only and up to 363 mSv if one includes the dose rec eived through the end caps with missing architectural mass. Real GCR reduction has been achieved however, the reduction is not significant enough to provide si gnificantly greater mission duration so more work is needed. Phase 2 intends to refine the vehicle configuration with added spacecraft architecture such as the p ropulsion system, logistics module, and a crew transfer capsule on the end caps of the habitat, all which is expected to contribute to the overall shielding efficien cy of the 8 Tm 6+1 coil configuration. The technology will be considered along w ith the potential scalability of the 8 Tm coils. External fringe fields will be evaluat ed and the compensator coil integration with the solenoid array loads analyzed. The magnetic loads and structural design concept will also be considered for eng ineering feasibility and refinement of the system shielding mass.

Technology Areas

Primary:

- TX06 Human Health, Life Support, and Habitation Systems
  - └ TX06.5 Radiation
    - └ TX06.5.3 Protection Systems

Target Destinations

Earth, The Moon, Foundational Knowledge